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(71) Applicant
STC plc

(Incorporated in United Kingdom)

190 Strand, London WC2R 1DU

(72) Inventors
Stephen John Turpin
Paul Andrew Timson

(74) Agent and/or Address for Service
M C Dennis,
STC Patents, Edinburgh Way, Harlow, Essex CM20 2SH

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(58) Field of search
G2J
Selected US specifications from IPC sub-class G02B

(54) Optical expanded beam termination

(57) An expanded beam termination for e.g. single mode fibres (A) may be constructed from a plano-convex lens (C) using angled interfaces (ϕ) to reduce unwanted reflection to very low levels. This is particularly useful in a coherent optical fibre reflectometer, or other coherent systems, where reflected signals can detrimentally affect the coherent laser source or where a low level return signal from a sensor has to be accurately monitored.

Fig.2.

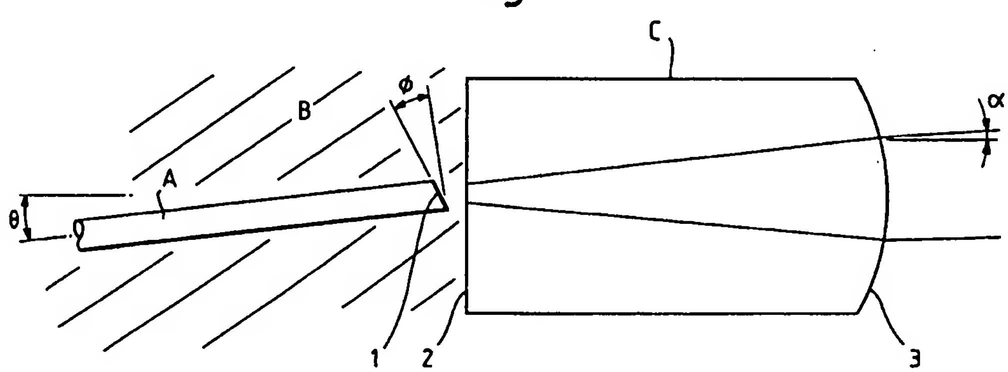

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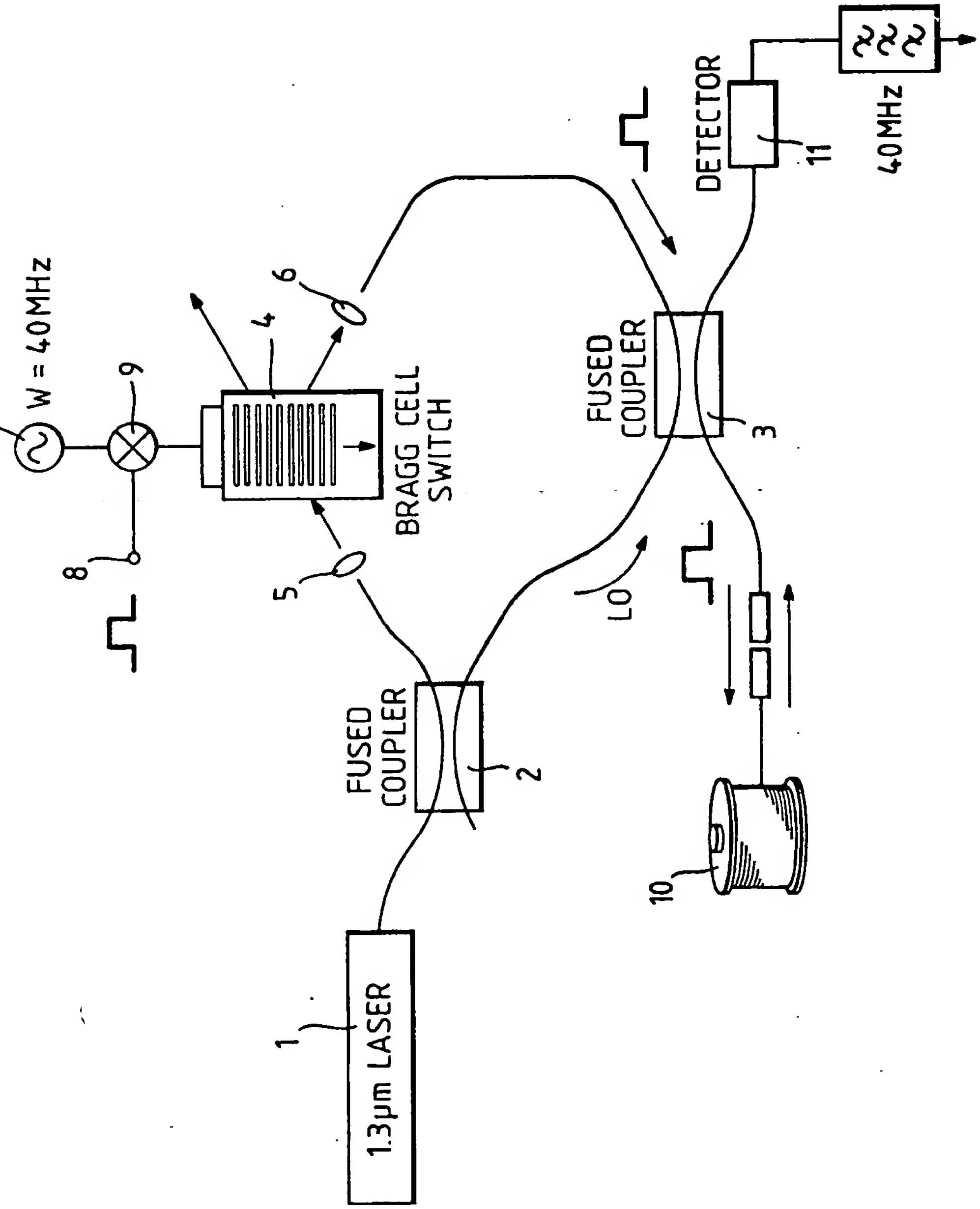
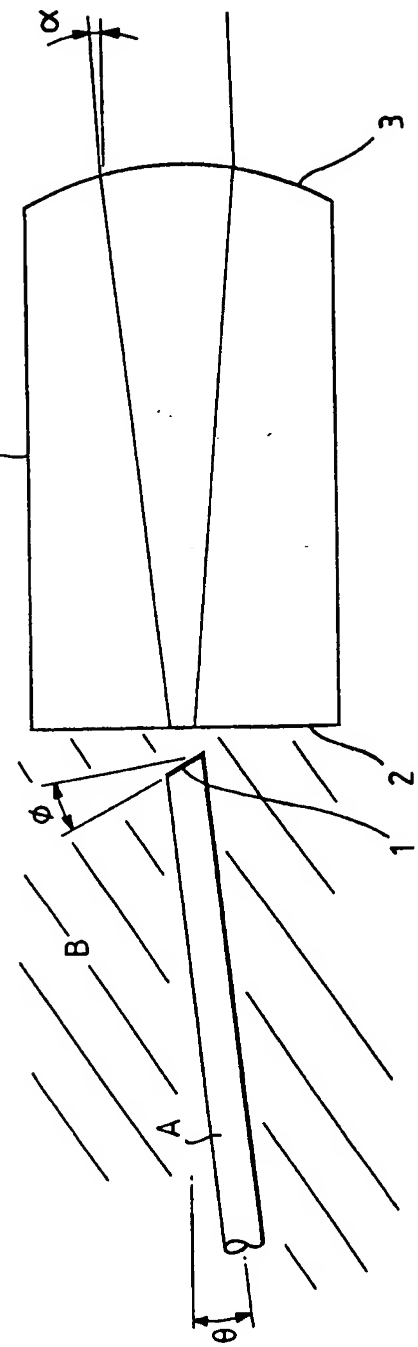
Fig.1.


1.3μm LASER
1
FUSED COUPLER
2
5
BRAGG CELL SWITCH
4
6
7
W = 40MHz
9
8
LO
FUSED COUPLER
3
10
DETECTOR
11
40MHz

2178554

Fig.2.



SPECIFICATION

Expanded beam termination

This invention relates to expanded beam terminations for optical fibres, particularly but not exclusively in coherent systems.

Expanded beam terminations are frequently used in fibre optic systems for such applications as enhancement of the launch power into a fibre from a laser source, or to convert fibre power into a free space beam of collimated light into which bulk optical components can be introduced with only minimum optical loss. This latter application has particular uses in fibre optic sensors and in optical time domain reflectometry when applied to single mode fibre systems. In particular, optical systems using heterodyning techniques (coherent techniques) use frequency shifting components which can conveniently be bulk optical components, such as acousto-optic Bragg cells, when combined with expanded beam terminations.

In such systems, particularly using single mode fibre transmission, the existence of a reflected signal from a termination can have a severe detrimental effect on performance.

It is an object of the present invention to minimise this detrimental effect particularly but not exclusively in a single mode fibre transmission system.

According to the present invention there is provided a coherent optical system including an optical component for processing wanted signals in the systems and a termination by which the component is optically connected to the system, and wherein the termination is so constructed and arranged that unwanted reflections from the termination are better than 40dB below the input power of the wanted signal.

According to another aspect of the present invention there is provided an expanded beam termination for connecting a first light guide to a second light guide, and a lens arrangement, the light guides having their end faces located at the foci of the lens arrangement and wherein at least one of the end faces is inclined at an angle ϕ to the normal of the axis of the respective light guide, where ϕ is greater than the light guide core acceptance angle.

In order that the invention can be clearly understood reference will now be made to the accompanying drawings, in which:–

Figure 1 shows diagrammatically an optical system of a coherent reflectometer incorporating two termination according to an embodiment of the present invention, and

Figure 2 shows schematically an expanded beam fibre optic termination according to an embodiment of the invention and suitable for use in the system shown in Fig. 1 as two opposing terminations collimating and receiving light accross a significant air gap.

Referring to Fig. 1 the coherent reflectometer comprises a coherent laser source 1 operating in this embodiment of 1.3μm. The system is of heterodyne form, using fibre couplers 2 and 3 and an acousto-optic Bragg cell 4 for optical pulse gating and frequency offset typically working at 40MHz. The Bragg cell 4 is coupled by expanded beam terminations 5 and 6, on the one hand with the fused coupler 2 and on the other hand with the fused coupler 3. The Bragg cell is driven by an oscillator 7 and switched by an input square wave at terminal 8 via a mixer 9.

A fibre under test, indicated by the reference numeral 10, receives pulses of coherent monochromatic light, and light reflected and backscattered from this fibre is mixed with a local oscillator signal in coupler 3, the local oscillator signal being derived from coupler 2, and the mixed light is applied to detector 11. A filter 12 centred at the Bragg cell frequency retreives a signal (typically 40MHz) containing both phase and amplitude information returning from the fibre under test.

The laser source 1 comprises a laser coupled to a length of line-narrowing single mode fibre, wherein the speckle-like nature of coherent backscatter causes the fibre to act as an external resonator with narrow passbands and narrows the intrinsic laser linewidth. This is the "wanted" signal in the system.

Any reflections from fibre terminations in the system, particularly at the expanded beam terminations 5 and 6, can upset the operation of the laser source. An external cavity on the laser produces very high coherence but a reflected signal from the expanded beam terminations can swamp the external cavity signal thereby reducing source coherence and degrading system performance.

For example a reflected signal we have measured from the planar face of the receiving lens of the expanded beam terminations lies in the range 25 to 33dB. This value is degraded considerably to approximately 20dB on alignment to a second termination.

It is proposed to utilise for the expanded beam terminations 5 and 6 in Fig. 1 modified terminations as shown in Fig. 2.

Referring to Fig. 2 there is shown schematically an expanded beam termination suitable for the terminations indicated schematically by reference numerals 5 and 6 in Fig. 1. In an expanded beam termination the existence of optical interfaces between the various components gives rise to a significant reflected signal, typically 20dB below the input power, as already discussed. This signal can be reduced by for example anti-reflection coatings on all interfaces (this gives some minor improvements—typically 30dB reflection), or by the careful selection of optical materials (giving somewhat greater improvements—typically 30dB reflection). However in accordance with

the present invention a more effective technique is described resulting in better than 40dB reflection and even better than 50dB. Referring to Fig. 2 the fibre A is held close to and at the focus of a lens C by a transparent adhesive B (indicated by cross-hatching). The interfaces between these components are indicated by the reference numerals 1, 2 and 3. All three of these interfaces contribute to reflection, although 1 and 2 are found to be generally dominant. As shown, the fibre end 1 is ground and polished to an angle ϕ to the normal, the value of which should be greater than the fibre core acceptance angle. In addition the fibre axis is inclined to the lens centre line by an angle θ where $\theta>\phi>0$. Reflections from interface 1 are now reflected out of the fibre A. Reflections from interface 2 can also be arranged to be outside both the core acceptance angle and the diameter by a careful choice of θ, dependent on the refractive index of material B, but always within the limits $\theta>\phi>0$. Furthermore the collimated light emerging from the lens is at an angle α to the lens centre line. This has the significant effect of avoiding a reflection from a second receiving expanded beam termination from the complimentary interfaces 1 and 2.

Reflections better than 50dB can be achieved with this configuration.

It should be understood that the complete termination includes a second plano-convex lens C and fibre A complementary to the ones shown in the drawing.

The termination described is useful in any coherent system susceptible to reflections e.g. where the laser source coherence may be degraded, in a sensor system using e.g. an interferometer where the wanted interferometer signal might be smaller than any unwanted reflections, and almost any coupler single mode optical circuit.

CLAIMS

1. A coherent optical system including an optical component for processing wanted signals in the system, and a termination by which the component is optically connected to the system, and wherein the termination is so constructed and arranged that unwanted reflections from the termination are better than 40dB below the input power of the wanted signal.

2. An expanded beam termination for connecting a first light guide to a second light guide, and a lens arrangement, the light guides having their end faces located at the foci of the lens arrangement and wherein at least one of the end faces is inclined at an angle ϕ to the normal of the axis of the respective light guide, where ϕ is greater than the light guide core acceptance angle.

3. A termination as claimed in claim 2, wherein the light guide axis is inclined at an angle θ with respecte to the lens arrangement, and wherein $\phi>\theta>0$.

4. A termination as claimed in any preceding claim wherein the lens arrangement comprises a pair of plano-convex lenses and wherein collimated light emerging from either lens is at an angle α to the lens centre line.

5. A termination substantially as hereinbefore described with reference to and as illustrated in Fig. 2 of the accompanying drawings.

6. A system substantially as hereinbefore described with referene to and as illustrated in Figs. 1 and 2 of the accompanying drawings.

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